



**Light Water Reactor Sustainability (LWRS) FY  
2020 CINR Webinar: RC-7,8,9**

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**Light Water Reactor Sustainability**

# Light Water Reactor Sustainability

- **Goal**
  - Enhance the safe, efficient, and economical performance of our nation's nuclear fleet and extend the operating lifetimes of this reliable source of electricity
- **Objectives**
  - Enable long term operation of the existing nuclear power plants
  - Deploy innovative approaches to improve economics and economic competitiveness of LWRs in the near term and in future energy markets.
  - Sustain safety, improve reliability, enhance economics
- **Focus Areas**
  - Plant Modernization Research and Development
  - Flexible Plant Operation and Generation
  - Risk-Informed Systems Analysis
  - Materials Research
  - Physical Security



*Nine Mile Point ~ Courtesy Exelon*

# Research Pathways & Focus Areas

## Plant Modernization

Address replacement of existing instrumentation and control technologies and enable plant efficiency improvements through a strategy for long-term modernization

## Flexible Plant Operation and Generation

Evaluate and demonstrate integrated energy systems that competitively produce electricity and non-electrical products to optimize revenue generation by nuclear power plants

## Risk Informed Systems Analysis

Develop significantly improved safety analysis methods and tools to optimize the safety, reliability, and economics of plants

## Materials Research

Understand and predict long-term behavior of materials in nuclear power plants, including detecting and characterizing aging mechanisms

## Physical Security

Validate methods and tools which can be used to implement an updated physical security regime to optimize physical security at U.S. nuclear power plants

# LWRS - Plant Modernization Research

Strategic Goal –Extend life and improve performance of existing fleet through modernized technologies and improved processes for plant operation and power generation

- Research Outcomes –Deliver technologies and results that significantly reduce the technical, financial, and regulatory risk of modernization
- Research Activities
  - Develop and demonstrate new digital instrumentation and control technologies and the means to enable significant improvements in operational efficiencies through their broad deployment
  - Develop new operational concepts that enable a transformation from labor centric to technology centric plant operation
- Research Outputs and Deliverables Include:
  - End State Requirements Studies
  - Evaluation of new technologies that enable modernization
  - Studies to enable the transition from current to future
  - Cost Benefit Studies
  - Technical Bases Studies
  - Implementation Recommendations & Lessons Learned
- Experience & Capabilities
  - Effective engagement with nuclear power industry
  - Coordinating industry efforts to achieve greatest impact



# CINR Workscope: RC-7

- Digital Instrumentation and Control
  - Develop an automated or semi-automated means of converting analog circuit design information (derived from electronic design drawings) to equivalent digital system function block logic (or other types of digital logic). This capability will further enable the function block logic (or other digital logic) to be automatically tested for correct operation either on the target digital platform or an equivalent simulator.
- Virtualized Distributed Control Systems for Nuclear Power Plants
  - Develop methods and techniques to allow virtualization of Distributed Control System (DCS) Purdue Model Level 1 hardware & software while maintaining key properties of current DCSs such as control segmentation, low latency, determinism, redundancy, fault tolerance, and graceful degradation.
    - Identify logical and physical architecture attributes/properties that enable virtualization of DCS Purdue Model Level 1 above the input/output interface to physical processes being monitored and controlled.
    - Demonstrate the proposed architecture ensuring current attributes (e.g. control segmentation, determinism, redundancy, fault tolerance, graceful degradation) of current DCSs at Purdue Model Level 1 are maintained.

# CINR Workscope: RC-7

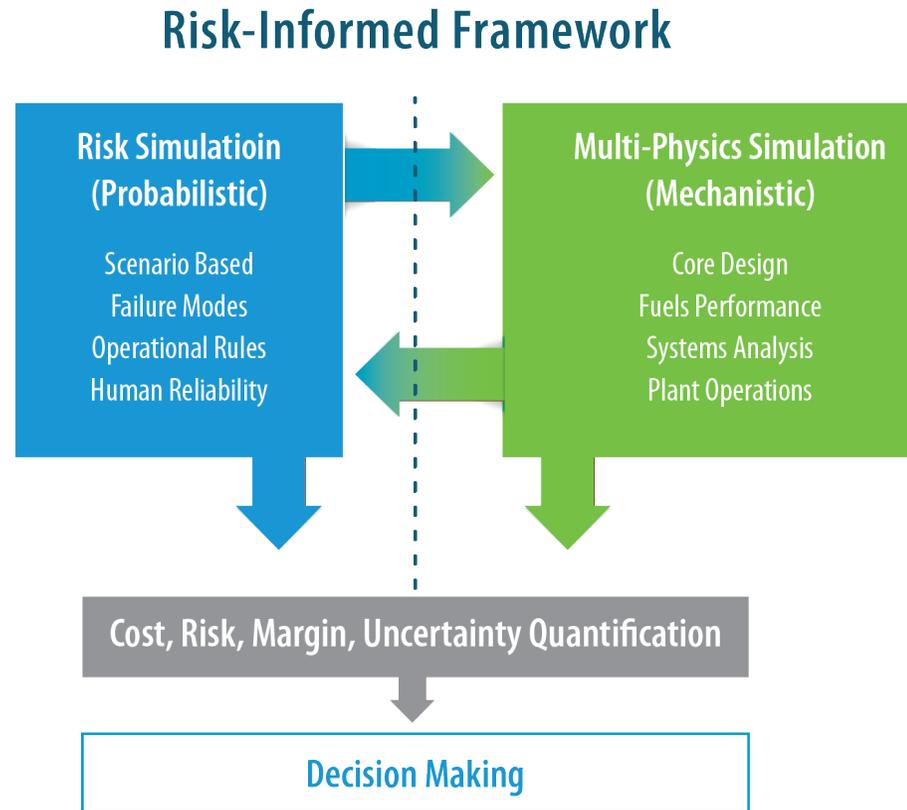
- Reducing Human Factor Uncertainty Using Artificial Intelligence in Operation and Maintenance of Nuclear Power Plants
  - Leverage advancement in technologies to automate possible O&M activities along with explainable artificial intelligence and machine learning research to analyze all the data sources.
  - Innovative and scientifically strong proposals in the area of artificial intelligence and machine learning techniques to reduce human error, variability, and uncertainty in data interpretation and decision-making.
  - The outcomes of the research are expected to provide consistent interpretation of data, diagnosis of any potential problem, estimate future state, make acceptable recommendation, and quantify the uncertainty in decision-making. The demonstration of the developed concept in a representative environment is preferred to enable implementation of the developed concept in a nuclear power plant.



# LWRS - Risk-Informed Systems Analysis (RISA)

Strategic Goal – Enhance nuclear power plant operations through the use of risk-informed tools and methods

- Research **Outcomes** – develop & demonstrate methods & tools to enhance risk analysis opportunities for risk-informed applications.
- Research **Activities**
  - Develop and demonstrate enhanced analysis capabilities of LWR systems through advanced methods, tools, and data to enable risk-informed margins management.
  - Conduct risk-assessment pilot project applications with industry to employ risk-informed methods, tools, and data to reduce operating costs.
- Research **Products**
  - Risk assessment methods & tools developed & demonstrated via pilot applications available for industry adoption.
  - Data, technical bases, and lessons learned from pilot projects that can be promulgated and scaled across industry to improve plant efficiency, increase confidence in their use, and reduce operating costs.



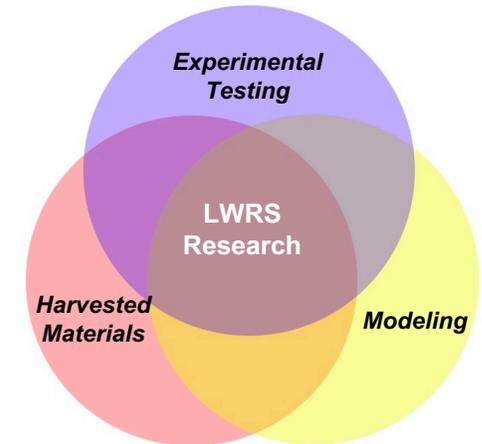
# CINR Workscope: RC-8.1

- **EVALUATION OF PHYSICAL PHENOMENA DATA IMPACT AND IMPROVEMENTS**

- Modeling the effects of physical events (fire, flood, high winds, etc.) in a nuclear power plant's risk assessment involves using data and a standard of practice guidance. This data and guidance typically use a conservative evaluation based on historical data, expert judgement, and experiments of the physical phenomena. Further, some of the historical experiments used in analysis today were performed before the availability of advanced measurement tools and controlled environments. These unknowns in input parameters and lack of resolution in results causes uncertainties and conservative decisions in order to cover knowledge gaps.
- Some small changes in results or reduction in uncertainty can have a large effect in results of a PRA model, such as the heat release rate curve in a fire model. However, recreating all these experiments may be cost prohibitive and often unnecessary. We request a project to research and evaluate the data used for hazard guidance in phenomena-driven areas and develop a method to determine significant contributors to uncertainty and determining what rerun or new experiments would be of most value (i.e., change in data/guidance leading to a difference in risk compared to the cost of new experiments). Possible work could include experiment determined to be of significant value for a specific phenomenon.

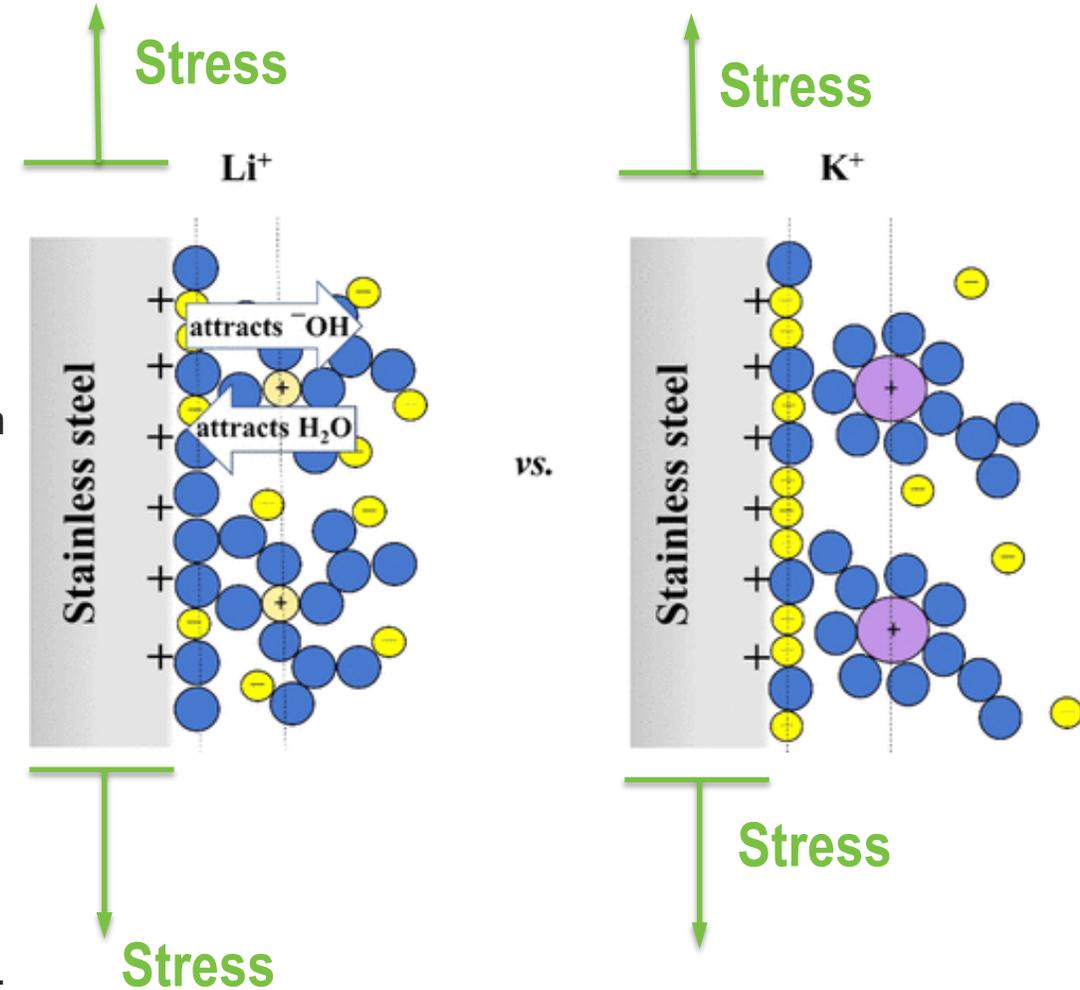
# LWRS - Materials Research

- Strategic goal - To develop the scientific basis for understanding and predicting long-term behavior of materials in nuclear power plants and to provide data and methods to assess performance of systems, structures, and components essential to safe and economically sustainable nuclear power plant operations.
- The research outcomes from this program will be used by utilities, industry groups, and regulators to inform operational and regulatory requirements for materials in reactor systems, structures and components subjected to long-term operation conditions.
- Research activities include:
  - Studies of harvested materials and other materials studies to measure the effects of environmental and service conditions on key material properties.
  - Modeling and simulation to develop multi-scale Multiphysics models of material performance to predict behavior and reduce experimental burden for long-term studies.
  - Research and development of monitoring techniques used to characterize the performance of key service materials in core components, cabling, concrete and other systems needed during long term operation.
  - Research and development to understand, control, and mitigate materials degradation processes

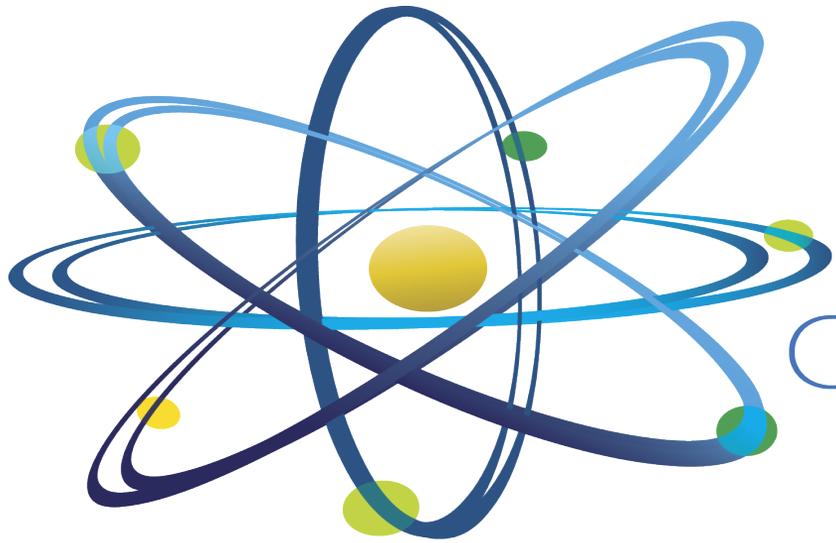


# CINR Workscope: RC-9.1

- Elucidating how the water chemistry affects the corrosion sensitivity of stainless steel in nuclear power plants
  - Reductions in the operating costs of nuclear power plants (NPP) are mandatory to pass the benefits of cost-effective electric power generation to the end-consumer
  - One possibility for cost reduction involves switching from LiOH to KOH as the alkalization agent, but impacts of KOH on the corrosion processes are not well-understood
  - Proposals are sought to develop new understanding of mechanisms and processes by which Li- and K-ions interact with alloy surfaces having variable microstructure in solution.
  - The study should aim to understand how changes in water chemistry may affect degradation and durability of NPP core internals, with consideration of mechanical stresses and effects of radiation
  - Systematic integration of advanced experimental analyses and modern modelling approaches (e.g., computational materials engineering, ICME) for developing new insights is highly encouraged.



# Questions?



Clean. **Reliable. Nuclear.**